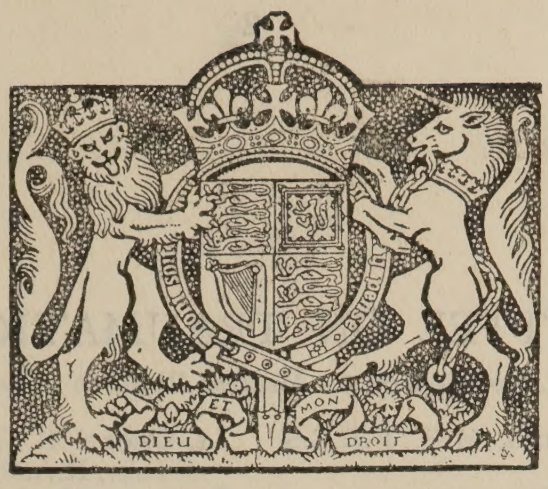


Medical Research Council
War Memorandum No. 1

Second Edition

THE TREATMENT OF "WOUND SHOCK"

(Instructions produced by the Medical Research Council Committees on Traumatic Shock and on Blood Transfusion, in co-operation with the Army Medical Service)

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses :
York House, Kingsway, London, W.C.2 ; 13a Castle Street, Edinburgh 2 ;
39-41 King Street, Manchester 2 ; 1 St. Andrew's Crescent, Cardiff ;
80 Chichester Street, Belfast;
or through any bookseller

1944

Price 6*d.* net

COMMITTEE ON TRAUMATIC SHOCK

(Appointed by the Medical Research Council)

Sir Ernest Rock Carling, M.B., F.R.C.S. (*Chairman*).
G. L. Brown, M.Sc., M.B.
Professor G. R. Cameron, D.Sc., M.B., F.R.C.P.
A. N. Drury, C.B.E., M.D., F.R.S.
Sir Henry Dale, O.M., G.B.E., M.D., F.R.C.P., P.R.S.
Professor Sir Howard W. Florey, Ph.D., M.B., F.R.S.
C. H. S. Frankau, C.B.E., D.S.O., M.S., F.R.C.S.
Professor Sir Francis Fraser, M.D., F.R.C.P.
Professor J. H. Gaddum, Sc.D., M.R.C.S., L.R.C.P.
Professor G. E. Gask, C.M.G., D.S.O., F.R.C.S.
Lt.-Colonel R. T. Grant, M.D., M.R.C.P., F.R.S., R.A.M.C.
Professor H. N. Green, M.Sc., M.D.
F. W. Holdsworth, M.Chir., F.R.C.S.
Surgeon-Commander W. A. Hopkins, O.B.E., M.D., R.N.
J. McMichael, M.D., F.R.C.P.E.
Air Commodore R. R. Macintosh, D.M., F.R.C.S.E., R.A.F.V.R.
Professor B. A. McSwiney, M.B., Sc.D., F.R.S.
Professor G. W. Pickering, M.B., F.R.C.P.
V. H. Riddell, M.D., F.R.C.S.
Brigadier L. E. H. Whitby, C.V.O., M.C., M.D., F.R.C.P.
Professor W. C. Wilson, M.B., F.R.C.S.E.
D. P. Cuthbertson, D.Sc., M.D. (*Secretary*).

COMMITTEE ON BLOOD TRANSFUSION RESEARCH

(Appointed by the Medical Research Council)

A. N. Drury, C.B.E., M.D., F.R.S. (*Chairman*).
H. F. Brewer, M.D.
Professor D. F. Cappell, M.D.
Professor T. B. Davie, M.D., F.R.C.P.
R. I. N. Greaves, M.B.
C. R. Harington, Ph.D., F.R.S.
Sir Percival Hartley, C.B.E., M.C., D.Sc., F.R.S.
Wing Commander J. R. R. Jenkins, M.R.C.S., L.R.C.P., R.A.F.
J. F. Loutit, B.M., M.R.C.P.
M. Maizels, M.D., F.R.C.P.
Major W. d'A. Maycock, M.D., M.R.C.S., R.A.M.C.
A. S. McFarlane, B.Sc., M.B.
P. N. Panton, M.B., B.Ch.
L. W. Proger, M.R.C.S., L.R.C.P.
Surgeon-Captain S. G. Rainsford, D.Sc., M.D., D.P.H., R.N.
W. S. Stanbury, M.B.E., M.D.
C. P. Stewart, M.Sc., Ph.D.
G. L. Taylor, M.D., F.R.C.P.
J. W. Trevan, B.Sc., M.B., F.R.C.P.
Janet Vaughan, O.B.E., D.M., F.R.C.P.
Professor G. Payling Wright, D.M., F.R.C.P.
D. P. Cuthbertson, D.Sc., M.D. (*Secretary*).

PREFACE TO THE SECOND EDITION

It will be noted that the present edition of this, the first of the Medical Research Council War Memoranda, differs very extensively from the first edition, issued in 1940 and reprinted several times since. The need for a revised edition, after four years of war and research experience, has not been precipitated by the discovery of any " dangerous " statements in the first edition ; on the contrary, the recommendations in the original pamphlet have been found in the main to stand up well to the test of time. Nevertheless, fresh evidence, changing points of emphasis, and new modifications of therapeutic procedure have necessitated the re-writing of the original Memorandum almost in its entirety. Although various aspects of the " shock " problem have been clarified by recent investigations, new factors have come to light which at present mainly emphasize the complexity of the subject. On account of this complexity, and by reason of the multiple factors which may produce the clinical state conveniently referred to as " shock ", stress has here been laid on the non-specific nature of the syndrome ; both the title and the text accordingly contain the word " shock " in inverted commas. There is still a need for intensive clinical and experimental research, directed to determining the explanation and practical significance of all aspects of the reaction of the body to injury.

THE TREATMENT OF "WOUND SHOCK"

CONTENTS

THE GENERAL EFFECTS OF INJURY ("SHOCK")

To the lay mind, "shock" may mean a state of prostration resulting from actual injury, or from the pain of injury, or from emotional reaction to the sight of an accident or the receipt of bad news. The term is thus liable to loose usage. In older surgical textbooks, shock was defined as "a condition of depressed vitality following injury". In the war of 1914–18, emphasis was laid on the circulatory effects of injury, especially those resulting from decreased blood volume. It is now appreciated that the remote effects of injury also comprise such diverse conditions as renal failure in crushing injuries, systemic effects of burns, fat embolism, severe complicating bacterial infections, etc. Two or more of these conditions may sometimes be present in a single case, particularly in war injuries, producing a complicated clinical picture. Operations and anaesthetics by themselves may reduce blood pressure. In battle, explosive gases or exhaust fumes in confined spaces may influence the picture in the wounded by causing poisoning, for example, by carbon monoxide. Following severe injuries of different organs and tissues of the body, any resulting circulatory depression may have various underlying mechanisms: head injuries, chest injuries, belly injuries and limb injuries will each have special features.

It is apparent, therefore, that "shock" is no single entity. As opportunity for the study of the special physiological consequences of severe visceral injuries is limited by their high early death rate, our knowledge of the general effects of injury is mainly derived from severe limb wounds and from burns, both of which bulk largely among war and civil casualties. It is generally agreed that a major feature of "shock" in these cases is an acute reduction of blood volume, or *oligaemia*. In the last war, oligaemia after injury was regarded as something rather mysterious, but it is now generally believed to result from loss of blood and plasma externally or into the traumatised area. Acute oligaemia resulting from haemorrhage is a common cause of the classical picture of "shock", with its clinical features of low blood pressure associated with pallor and rapid pulse of poor volume. Of all the causes of "shock", haemorrhage has been more completely studied than any other and, for that reason, it will be discussed in detail. Other general effects of injury, and factors such as those mentioned in the preceding paragraph, may produce or modify the "shock" picture. These will be discussed subsequently.

MECHANISMS IN OLIGAEMIC "SHOCK" FROM HAEMORRHAGE

When the blood volume is acutely reduced by haemorrhage, the venous side of the circulation is at first affected more than the arterial. Consequently, the intravascular pressure in the great veins near the heart is lowered. This leads to decreased filling of the heart, and reduction in its output. It has been demonstrated that, apart from the possible complication of vasovagal collapse (see p. 7), the withdrawal of up to two pints of blood may be well tolerated in man, and lead to no more than a slight fall in arterial pressure; further fall is probably prevented by vasoconstriction which affects particularly the skin and splanchnic area. Blood losses beyond this amount are apparently necessary before the full classical picture of oligaemic "shock" is seen.

In haemorrhage the heart rate is quickened, the pulse commonly rising to rates of 100–120 per minute. Rates more rapid than this (140–160) are not commonly seen, except in the most extreme cases. Anaesthesia tends to increase the rate.

The relation between the clinical condition and the degree of blood volume reduction requires further study, as the methods hitherto used are open to

criticism. It is known, however, that a 25 per cent. reduction in blood volume may be associated with only slight symptomatic disturbances. Losses greater than this are likely to produce a considerable fall of blood pressure, and when 50 per cent. or more of the blood volume is lost, the fall is profound (often to below 60 mm. Hg systolic pressure).

When blood is lost, absorption of tissue fluid tends to restore the blood volume. In man, this mechanism operates relatively slowly and may only be completed one to three days after a severe haemorrhage. In the first hour or so after the injury, the haemoglobin is seldom reduced by more than 15 per cent., no matter how severe the blood loss may have been. In the early hours after injury, haemoglobin levels are thus no index of the severity of the blood loss.

When a stage of severe post-haemorrhagic anaemia is reached, the haemodynamic picture changes to one in which the pulse becomes full and bounding, with a high pulse pressure. This state is not usually seen until 20–30 hours have elapsed from the time of bleeding.

It is known that the early and complete restoration of blood volume brings about recovery in nearly all cases of haemorrhagic " shock ". If, however, the blood pressure has been low for several hours, restoration of the blood volume may not suffice to produce recovery. The cause of this so-called " *irreversible state* " is still uncertain. Prolonged anoxia may damage the vital centres in the medulla, and the heart may also suffer as a result of poor coronary flow.

Transfusion even at a late stage may still produce dramatic improvement. Sometimes the blood pressure may be restored by quantities of blood inadequate to make up the normal blood volume. This may play some part in inducing a liability to collapse later, e.g., with handling of injured limbs, or small renewed blood loss.

Clinical Features of Oligaemic Shock

While established " shock " is easy to recognize, it must be appreciated that in the early stages the clinical appearance of the patient may be deceptive and the blood pressure may even be high. As will be emphasised later, in such patients the severity and the nature of the injury are the best guides in judging the need for transfusion. In established " shock ", the patient is pallid with a cold skin, which may be moist with sweat. Temperature may be subnormal. Mentally, he is usually clear, but he may be either talkative and abnormally cheerful (euphoric) or apprehensive and restless. In spite of severe wounds, he usually does not complain of much pain. Vomiting may occur, particularly with extensive injuries. A rapid pulse of poor volume precedes any profound fall in arterial pressure, but as the severity progresses, the blood pressure falls considerably and the pulse may become imperceptible. The venous pressure is low. Although the skin is generally intensely pale, cyanosis in the nails and lips may indicate the sluggish nature of the circulation.

The rate of respiration is not obviously increased, but sometimes air-hunger may be seen—an alarming feature which may precede death.

The subject complains of intense thirst, and fluids drunk may be immediately vomited ; the urinary flow is scanty until recovery occurs.

Post-traumatic Hypertension

In the early stages following injury, even when associated with considerable blood loss, a pallid patient with a rather poor pulse volume may be found to have an abnormally high systolic arterial blood pressure, of 150–170 mm. Hg. The cause of this rise of pressure is uncertain. The patient may recover without special treatment, but sometimes the picture changes to that of oligaemic

" shock," when indications for transfusion may develop. With severe injuries, transfusion should be dictated not by the blood pressure level but by the severity of the wound and the blood loss.

VASOVAGAL COLLAPSE

This important and common condition frequently complicates the picture of haemorrhage, and occurs in about 5 per cent. of ordinary blood donors losing just over 400 c.c. of blood, its frequency increasing with the loss of larger amounts. It is also seen after painful stimuli such as those arising from sprains, fractures and burns, but it may occur in susceptible individuals after the most trivial injuries and from non-painful sensory stimuli, carrying associations of trauma, especially when the subject is upright.

The sequence of events in vasovagal collapse has been most closely studied following venesections in man. During or after haemorrhage, the blood pressure, at first maintained, may suddenly fall profoundly and the pulse become slow ; the patient feels faint and may lose consciousness. The fall of arterial pressure is not due to the cardiac slowing : it is due to vasodilatation, especially in the muscles.

Clinical features.—The condition usually comes on *early* after injury, but may occur at any time subsequently, being precipitated by the upright posture, further blood loss, manipulations or operations. It may even occur when imminent danger is escaped. Warning signs are pallor, yawning, over-breathing, a sensation of heat, and a profuse clammy sweat ; waning consciousness, or coma, may follow. Vomiting occurs sometimes and convulsions rarely. The systolic blood pressure may fall in mild cases to 80 mm. Hg, and in more severe cases to 50 mm. Hg, or lower levels at which the pressure cannot be recorded. The pulse rate falls *pari passu* to levels which may be as low as 40 per minute, but in an average case it is usually 50–60 per minute.

The condition ordinarily passes off quickly if the patient is kept flat or in the head-down position. If the attack is in any way prolonged, it may indicate haemorrhage of some considerable severity. In such cases, recovery occurs without transfusion, but subsequent operation is likely to bring on further collapse, which may only be treated satisfactorily by the administration of blood, plasma or serum. Vasovagal collapse may occur late, as well as early, after haemorrhage.

EFFECTS OF TISSUE TRAUMA

Effects of Tissue Trauma in General

While oligaemia is a main factor in the production of " shock " in injured subjects, there is good clinical evidence that tissue trauma adds considerably to the seriousness of the condition and may, in some instances, be the dominant factor. The mechanisms involved are still obscure. Products of tissue destruction enter the blood stream when circulation is established through necrotic or partially devitalised tissues (cf. crushing injuries). Nervous reflexes may be involved, e.g. vasovagal reactions may come into play when the injured tissues are handled. Other evidences of a generalised disturbance following tissue trauma are to be found in :—

(i) slight fever accompanying major wounds and burns which is not due to infection (traumatic fever) ;

(ii) increased protein breakdown, with loss of nitrogenous and other katabolites, also creatinuria ;

(iii) post-traumatic anaemia not accounted for by haemorrhage (e.g. after burns).

Effects of Special Forms of Trauma

Burns.—The mechanism of " shock " following burns is still imperfectly understood, but there is widespread agreement that the most important factor is oligaemia due to a local increase in capillary permeability in and around the burned area, with resulting loss of plasma from the blood stream into the tissues and, externally, from the surface of the burn. It is known that the local loss of fluid into the tissues around a burn begins early—within an hour or two of the injury—and that, in cases of severe or extensive burns, it demands urgent and energetic treatment by fluid replacement if it is to be successfully combated. Owing to the large local escape of plasma from the blood stream, haemoconcentration is more constantly found and is usually greater in " burns shock " than in " shock " associated with other kinds of trauma. Observations on the degree of haemoconcentration (e.g. haemoglobin measurements) thus provide a useful though not absolutely reliable, index of the effects of treatment. The state of abnormal capillary permeability which is responsible for the plasma loss in burns ordinarily continues for 24–36 hours from the time of injury, and becomes progressively less thereafter.

The usual clinical picture in " burns shock " is not widely dissimilar from that of other types of oligaemic " shock ", but it is liable to be much influenced by the conditions of observation and treatment. Patients given morphine in full doses, received in a warm room, and having their burns covered by sulphonamide dressings, are often restless and apathetic, and slightly cyanosed ; the skin is dry, thirst is usual and vomiting frequent ; the pulse is small but not thready, the blood pressure often raised. In the more severe cases, apathy deepens into stupor, blood pressure falls and pulse rate rises, urinary output is low and there is often pyrexia.

Haemoconcentration and the other circulatory derangements associated with " burns shock " can be largely prevented if serum or plasma is transfused *early*, and in sufficient amount to allow for the leakage of much of the fluid through the altered capillaries. Such transfusions should usually be maintained by slow drip for most or all of the first 24 hours.

During the first few days, the clinical course of patients with large burns is very variable. If given sufficient plasma or serum to prevent or relieve acute oligaemia during the first 24 hours, most patients remain free from serious symptoms unless, or until, bacterial infection supervenes. In all probability the cause of a less favourable course is not always the same. If too little fluid is transfused, or if transfusion is delayed until oligaemic " shock " has become profound, haemoconcentration and other signs of " shock " persist until death, which occurs usually between 20 and 30 hours after injury. In other patients who appear to be making good progress, the condition begins to deteriorate at about 30 hours after injury : stupor develops and gradually deepens into coma, urinary output falls, the pulse and respiration rates increase, vomiting is frequent and persistent, and the temperature rises until death occurs with hyperpyrexia, about 60 to 90 hours after injury. By the time these symptoms begin, haemoconcentration has usually disappeared and it may even be replaced by haemodilution.

It is possible that in a few cases deterioration is a result of severe and prolonged anoxia at an earlier stage, the condition having become irremediable because of damage to vital organs. Other cases, however, are not so easily explained. Bacterial infection of the burn may occur at an early stage, unless proper measures are taken to prevent it, but in many instances infection can be excluded with reasonable certainty. Absorption of toxic products from burned tissues has been suggested as a possible cause, hence the term " toxaemia " has been given by some authors to the syndrome. This suggestion at one time seemed highly plausible, because severe liver necrosis was often found after death at this stage. It is now recognised, however, that

severe necrosis of the liver after burns probably occurs only with tannic acid treatment, and results from the absorption of tannates. The evidence of toxic absorption from burns in general has thus been weakened, but the possibility cannot yet be excluded, because on occasion this severe form of illness has occurred with most if not all forms of local treatment hitherto tried.

Disturbances of the circulation at this stage may be produced in yet another way. Fluid from oedematous tissues is reabsorbed into the circulation when the injured capillaries regain their normal permeability; absorption begins about 30–40 hours after the injury. If absorption is rapid, and at the same time the urinary output remains low, the volume of plasma in circulation will rise steeply. This complication is most likely to arise when an extensive area of the skin surface has been deeply burned, when very large volumes of fluid have been transfused during the first 24–30 hours, and, in consequence, the tissues have become grossly oedematous, and when little urine is being excreted. It will be gravely aggravated if transfusions or infusions are continued under those conditions. Furthermore, there is a risk of pulmonary oedema if excessive amounts of intravenous fluid are given, particularly in cases where the lungs or air-passages have themselves been damaged by the inhalation of flame or hot gases.

The danger of giving too large an amount of intravenous fluid for the treatment of " burns shock " therefore requires to be kept in mind, as well as the danger of giving too little. The assessment of the burned patient's requirements in respect of intravenous fluid calls for a nicety of clinical judgment (with due consideration of his age, size, the extent of his burns and the state of his circulation), supported, when possible, by repeated observations on the degree of haemoconcentration. For further recommendations on the treatment of " burns shock ", see p. 18.

Crushing and compression injuries.—In subjects buried by explosions, the weight of wreckage or earth on a limb may be such as to arrest its circulation until the weight is taken off. On restoration of the circulation through *dead* muscle, the diffusable constituents of necrotic muscle tissue, including potassium salts, phosphate, creatine and myohaemoglobin, are washed into the general circulation. The latter pigment is excreted in the urine, giving it a red or smoky colour. Renal failure ensues, with death in two-thirds of the cases at the end of the first week (see p. 19). A similar sequence may follow other types of limb injury, particularly when the blood supply is curtailed.

At the onset, the affected limb is usually paralysed. Whealing and blistering of cutaneous bruises is notable, and general swelling soon becomes obvious. This is associated with local plasma transudation, haemoconcentration and oligaemic " shock ". The restoration of the blood volume by plasma or serum transfusion raises the blood pressure, though continued local swelling may necessitate further transfusion. In spite of restoration of a normal arterial pressure, the condition of the limb itself frequently gives rise to anxiety, as it becomes tense and brawny with oedema fluid, the main arteries are often in spasm, and gangrene may set in at the periphery. If the patient recovers, local muscle atrophy and fibrosis, or Volkmann's ischaemic contracture, may ensue.

It should be stressed, however, that the risk to life from renal failure should take priority over the local condition of the limb when treatment is considered (p. 19).

Blast injuries.—Blast injuries most commonly produce intra-pulmonary haemorrhage, with features of dyspnoea and haemoptysis. In the presence of this type of injury, blood transfusion is often disappointing and, indeed, dangerous. Underwater blast produces also intra-abdominal injuries with haemorrhage.

OTHER COMPLICATING FACTORS

Fat embolism.—Blockage of pulmonary capillaries by fat globules from injuries of the long bones and limbs may contribute to the development of a special form of circulatory collapse. Symptoms may develop after an interval of 6–72 hours from the time of injury. There may be cerebral symptoms, varying from irritability to coma, and petechiae in the skin, resulting from passage of fat globules through the lungs into the general circulation. Collapse from fat embolism does not respond to transfusion. The condition may be suspected if the cervical veins become engorged during transfusion.

Toxic Gases.—Lung irritants, such as phosgene, cause delayed pulmonary oedema. In severe cases, the blood becomes concentrated and the patient passes into a state of circulatory collapse, with a rapid, feeble pulse and a clammy skin. The failure of the lungs to absorb oxygen makes this type of "shock" particularly dangerous, but the cyanosis may be detectable only on the lips and the tips of the ears.

The exposure of large areas of skin to vesicants, such as mustard gas or lewisite, may also cause haemoconcentration. This may be partly due to local fluid loss, but is mainly due to the effects of the poison after absorption into the general circulation. The effects of these substances are described in the *Medical Manual of Chemical Warfare* (H.M. Stationery Office, London, 1943).

Severe carbon monoxide poisoning *per se* can produce a state of hypotension. The history of exposure to explosive or exhaust gases in a confined space—and the accompanying features, such as mental confusion, glycosuria, patchy pulmonary atelectasis—help in making the diagnosis. The cause of the low blood pressure is not completely understood.

Infections.—Severe and overwhelming bacterial infections are well known to produce a fall in blood pressure. In abdominal wounds, peritonitis may be responsible. In muscle wounds, an infection may be established within a few hours, e.g. gas gangrene. Infection also complicates burns. Low blood pressure in such cases usually does not respond to transfusion, or the response is incomplete and transient.

Anaesthesia.—Anaesthesia may add considerably to the complexities of the circulatory depression in the injured state. Patients who are "shocked", or who have just been resuscitated from "shock", are peculiarly susceptible to the action of anaesthetic drugs, and relatively small amounts of any anaesthetic will provide adequate anaesthesia in such cases. The normal circulatory adjustments to change of posture are modified under general anaesthesia, and sudden alterations may lead to cerebral anaemia. Chloroform has a toxic action on the myocardium, especially in conditions of anoxia, and its use is likely to be followed by a high mortality in "shocked" patients. With increasing concentrations of ether, vaso-dilatation may become a factor leading to a further fall of blood pressure. If anoxia is allowed to accompany nitrous oxide anaesthesia, this will lead to further depression of the respiratory and vasomotor centres in the "shocked" patient. Respiratory depression, with consequent anoxia, may follow excess of pentothal sodium or hexobarbitone. As spinal and splanchnic anaesthesia lower blood pressure, they are contraindicated. Large-scale regional anaesthesia may cause vasodilatation of a whole limb, the possible effects of which should be borne in mind. Local anaesthesia is not known to have any deleterious effect in the "shocked" patient. (For further details regarding anaesthesia in "shocked" patients, see p. 16.)

Dehydration.—After haemorrhage, extravascular fluid is drawn into the blood as a compensatory mechanism. Where, however, the subject is already dehydrated from any cause, this mechanism may be relatively ineffective, and the condition of the circulation may be made worse, e.g. by vomiting in abdominal injuries.

TREATMENT

General Principles

Casualties with severe wounds, and especially those with the clinical signs of " shock ", must be taken at the earliest possible moment to a unit equipped for transfusion. Every unnecessary link in the evacuation chain should be eliminated. Obvious haemorrhage must be arrested, injured limbs gently but effectively immobilised, the patient reassured, thirst allayed (except where fluids by mouth are contradicted by the nature of the injury), and, if pain is likely to arise in transit, morphine may be given. If morphine is used, the fact should be notified to medical units in the rear, or to the Casualty Receiving Hospital, e.g. by lettering the patient's forehead " M$\frac{1}{6}$ " together with the time of administration, or by recording the information on a label attached to the casualty.

A patient admitted to a Casualty Receiving Hospital who is judged by the medical officer in the Receiving Room to be unfit for immediate operation by reason of any form of " shock " should be admitted to a special *Resuscitation Ward*, where the essential rest and quiet, so impossible to obtain in a busy general surgical ward, can be ensured, and where measures designed to restore the circulation can be quietly carried out.

Generally speaking, the longer operation is delayed, the worse for the patient ; and where " shocked " patients happen to be admitted in numbers permitting immediate operation, or with very severe wounds, there is a good deal to be said for carrying out resuscitation measures in the operating theatre just prior to and during operation. It cannot be too strongly emphasised that damaged tissue should be removed as soon as possible. Wound excision should be performed quickly but with due regard to gentle handling of the tissues, and to haemostasis. Calm assessment and rapid decision by an experienced medical officer are needed. The management of the severely wounded requires continuous and assiduous attention. The condition of " shock " is liable to rapid deterioration and almost equally rapid improvement. Careful recording of blood pressure and other clinical details are of the utmost value in indicating the need for transfusion on the one hand, and the optimum time for operation on the other. Medical officers skilled in transfusion techniques should supervise the work of resuscitation, with as adequate a staff of assistants, nurses and orderlies as circumstances permit. In organisation, account should be taken of the fact that 10–15 per cent. of battle and air-raid casualties admitted to hospital will require transfusion. The best interests of the patient are served by an early and complete examination. If splints have been applied, these should not be removed, but otherwise the patient should be completely undressed, and notes made of *all* the injuries, as well as of his general circulatory state. If circumstances permit, the cases are reviewed as soon as possible after admission by the surgeon, anaesthetist and physician together, and a provisional order of priority for operation decided. On the other hand, when patients are received in large numbers and priority for operation has to be decided, experience has shown that the key to the rapid handling of casualties is to pick the best medical officer available for pre-operative and resuscitation work, and to accept his decisions on priority. " Shock " cannot be treated without careful dovetailing of the measures of resuscitation to the necessary surgical interventions. Patients whose blood pressures have been restored to normal may deteriorate as a result of failure to operate at the earliest possible moment. Undue delay in operation leads to such complications as infection and further unnecessary loss of blood.

In the resuscitation wards, local treatment is not attempted, apart from such obvious requirements as the arrest of free haemorrhage or the adjustment of a splint on a painful or improperly immobilised limb.

Arrest of Hæmorrhage

Upon admission of a casualty to a resuscitation ward, the site of wounding should be examined to confirm arrest of haemorrhage, and if a tourniquet has been used, to decide as to its removal. If a limb is so severely mangled that conservation is unlikely, and the tourniquet is found in a satisfactory position close above the site of injury, it should be left there until amputation can be performed ; removal of the tourniquet in such circumstances is inadvisable, because extensive plasma loss quickly occurs into the injured area, even though there is no bleeding. If removal of the tourniquet is unavoidable, arrangements for a transfusion should be made.

In all other cases the tourniquet should be loosened and can generally be dispensed with. When a limb is not hopelessly damaged, complete occlusion of the vessels must cease at the earliest possible moment. Tourniquets are dangerous instruments, and difficult to apply effectively without a risk of local damage. After they are released, it is necessary to keep a look-out for renewed bleeding when the blood pressure is raised by transfusions. It is better to use strong bandages bound tightly over the dressing and several layers of wool, applying the pressure, in accordance with first principles, at the bleeding spot. Fabric bandages may also be used to apply firm pressure to the whole limb, to limit plasma loss ; rubber bandages are apt to cause too much ischaemia if applied thus, but if available, one may be used at the site of bleeding.

Army Organisation : Treatment in the Field before Reaching Advanced Surgical Centre

The treatment that can be given in forward medical units (Regimental Aid Posts, Advanced and Main Dressing Stations) is largely governed by the military situation. In forward units, the main concern is efficient first aid, obvious conservative and symptomatic measures and rapid clearance, with a view to obtaining efficient surgery at the earliest opportunity. In theory, a triage of wounded is carried out at a Main Dressing Station ; thereby they are divided into three groups : (*a*) Group 1, for whom transfusion is essential before further evacuation ; (*b*) Group 2, for whom surgery is urgent ; (*c*) Group 3, for whom neither surgery nor transfusion is urgent.

Facilities for transfusion are therefore provided at the Main Dressing Station, and sometimes even further forward, in order to deal with the Group 1 case. In principle, however, transfusion is carried out in these forward posts only in order to induce sufficient recovery to enable evacuation to be carried out. If possible, the source of bleeding is controlled at the same time. When recovery has begun, the most successful end-results are obtained by rapid evacuation in an ambulance with a transfusion in progress. The object is to bring the patient to the surgeon in good condition, so that the final stages of resuscitation can be quickly followed by the necessary surgery. Likewise, the Group 2 case can be embarked in an ambulance without delay, with a transfusion in progress. War experience has shown that this last procedure is the best for patients with abdominal wounds in whom the bleeding cannot be controlled, and indeed for any wounds which fall into this uncontrollable category, particularly if the injury is massive. The first point at which there is plentiful provision for transfusion, as well as full surgical facilities, is usually at a Field Dressing Station to which has been attached a Field Surgical Unit and a Field Transfusion Unit, thus establishing a complete Advanced Surgical Centre.

General Measures

Rest.—Rest in bed or on stretchers is an obvious essential; except in cases of head and chest injuries, the foot of the bed should be elevated 9 inches, as this measure will often raise the blood pressure by 5–15 mm. Hg. While the patient is awaiting evacuation, the foot end of the stretcher should be similarly elevated.

Warmth.—Warmth has an important place in the treatment of patients who are chilled by exposure to cold and wet. Such a patient should have his wet and dirty clothes removed. He should be clad in warm pyjamas and placed in a bed warmed by hot-water bottles, and be given hot drinks. More elaborate heating arrangements are unnecessary, and it is always undesirable to over-heat the patient. Enough cover and warmth for comfort are now thought to be the optimum conditions. Vigorous heating beyond this point is harmful, probably because the vasodilatation in the skin accentuates the blood lack in other tissues, due to the existing oligaemia.

If a tourniquet must be kept in place, or if the blood supply to a limb is seriously diminished by pressure bandages, the parts should be kept cool. Cooling decreases the rate of metabolism of the tissues, and reduces both the nutritional needs and the production of metabolites that may be injurious. Cooling must not be so severe as to risk frostbite. The appropriate environmental temperature is not below 50° F. If the atmospheric temperature is at this level, simple exposure of the limb will suffice; if the air is colder, the limb must be protected once it has cooled to the desired degree.

Stretcher-bearers should be familiar with the proper use of waterproof sheets and blankets, as described in R.A.M.C. Training Pamphlet No. 1 (1943). When blankets are not available, protective clothing should be placed between the canvas of the stretcher and the patient, rather than on top of the patient.

Relief of Pain, Restlessness and Apprehension.—Patients may be afraid of further injury by bombing or other enemy action, and much can be done to reassure them by the efficiency and bearing of the attendants. In addition, morphine may be required. Morphine is often necessary for the relief of pain: $\frac{1}{6}$ grain given *intravenously* where possible is most satisfactory, for when the condition of the circulation is poor, absorption from the subcutaneous tissues is slow and unreliable. It will often be found that pain is not complained of until the blood pressure is recovering with transfusion, and the injection may then be made conveniently into the rubber tubing of the transfusion set, and thereby washed into the circulation.

As far as possible, morphine should be reserved for pain and apprehension. Its routine use is undesirable, and there have undoubtedly been many cases of morphine poisoning from its too liberal use in the past. Slow absorption from the cold skin may lead the unwary into further subcutaneous administration, the large total dose being subsequently carried into the circulation as the latter improves. The practice of giving $\frac{1}{2}$ grain subcutaneously soon after wounding is still far too frequent in the field. After resuscitation, morphine may, of course, be given subcutaneously.

Dehydration.—Dehydration may on occasion contribute to "shock". All wounded subjects can be assumed to be suffering from some degree of depletion of extravascular fluid reserves. All casualties, except those who are unconscious or who are suffering from abdominal wounds, should be given copious and repeated drinks; generally they are thirsty. If vomiting is troublesome, sips are better. Special orderlies or nurses should be detailed to encourage and assist patients to drink. Any delivery device which allows water to be swallowed with a minimum of effort and movement will be of value. Warm sweetened tea or coffee should be given whenever possible. If necessary, the rectal route may be used to supplement oral administration; warm,

half isotonic (0·45 per cent.) sodium chloride solution (approximately half teaspoonful per pint) is the most suitable fluid for rectal injection. In the field, rectal administration of saline is unsatisfactory ; it is not easy to accomplish ; the fluid is usually returned and the bowel is often loaded with faeces which are evacuated on to the stretcher.

Intravenous saline and glucose-saline infusions are not now regarded as an adequate method of making up the blood volume, as their effect is only transitory. Where dehydration complicates the picture, intravenous saline may be used in quantities not exceeding three litres per diem to supplement previous transfusion, e.g. in cases of abdominal injury.

Plasma loss in injured tissue is greatly increased by movement. Immobilisation is, therefore, of very great importance.

Restoration of Blood Volume by Transfusion (*see Appendices A, B and C for technical details*).

Where oligaemic "shock" is profound, there is no known measure other than transfusion which will save life. However, when the oligaemia is due to toxic gases which induce lung irritation when breathed, such as phosgene, mustard gas and lewisite, or predispose to pulmonary oedema through absorption from the skin, e.g. lewisite, transfused fluid leaves the circulation immediately through the damaged capillaries, and there is experimental evidence that transfusion is not only useless in these cases but may indeed be harmful. Other conditions causing pulmonary oedema may contraindicate transfusion (see p. 15).

When to Transfuse

When, as a result of injury, the systolic blood pressure is below 90 mm. Hg. and the pulse is rapid, transfusion should not be delayed. In intermediate cases, skilled judgment may be required, and if early spontaneous recovery does not occur, transfusion should be begun. If there is any doubt, it is better to give than to withhold transfusion.

From what has already been said, it is obvious that some patients may lose considerable amounts of blood (25 per cent. of the blood volume or more) and show little reduction of systolic pressure. If operation has to be undertaken in such patients, a profound fall of pressure may ensue. If, therefore, there is (*a*) evidence of severe blood loss, (*b*) severe wounding with traumatised tissue still *in situ* and exceeding two fists in volume, transfusion should precede and accompany operation, even if the preoperative blood-pressure level is apparently satisfactory. In such cases operation must not be delayed.

Conversely, transfusion should not be withheld, no matter how near to death the patient appears to be. The apparently moribund and pulseless patient may sometimes be successfully resuscitated by massive transfusions.

Choice of Transfusion Fluid

Where blood loss is the major factor in the production of "shock", blood is naturally the fluid of choice for replacement ; where plasma loss is indicated by haemoconcentration (e.g. after burns or crushing injuries), plasma or serum should be used.

Other factors, however, have to be considered. Firstly, plasma or serum, either natural or dried, may be more accessible and can be given to any patient, without fear of haemolytic reactions. For this reason, plasma or serum is particularly suitable for beginning transfusion. Where the volume of transfusion required is moderate (up to two bottles), plasma or serum alone can be given with safety. Where larger transfusions are required, blood should be used, or a change over to blood made after giving one or two bottles of plasma (or serum).

Amount and Rate of Administration

The volume of blood (or other fluid) transfused should be determined by the response of the patient. The aim is to restore the blood volume to

normal as soon as possible. In a series of war casualties requiring transfusion, the average volume required was 3 pints. In some severely wounded cases, an amount approaching the whole blood volume may be needed. The sooner the blood pressure is restored to normal, the better for the patient. The fluid used may be given as rapidly as it will run under gravity through the largest infusion needle or cannula. As much as 100 c.c. per minute may be given in this manner. If the veins are in spasm, a hot water bottle laid over the arm is often all that is required to relax them, or blood may be forced in by a rubber bellows on the air inlet tube of the transfusion bottle, or by a two-way syringe. If air is forced into the transfusion bottle, care must be exercised to disconnect the bottle before all the blood is run into the vein, or a fatal air embolism will occur. The rapid transfusion flow should be maintained until the blood pressure has risen to over 100 mm. Hg, when it may be reduced to a drip. On no account should the transfusion be dismantled until operation is over, and the observer is satisfied that all risk of further blood loss has ceased. The maintenance of a drip during operation makes it easy to give more blood rapidly should this be required.

Risks of Over-Transfusion

Danger of pulmonary oedema.—A previously normal subject in a state of oligaemic "shock" cannot be overloaded by reasonable transfusion volumes (e.g. 2 to 3 pints), so long as the infusion rate is slowed after a normal blood pressure level is reached. The normal cardiac output, of about 5 litres per minute, will have been considerably reduced in oligaemic "shock", and the heart can easily cope with blood transfusions at the rate of 100 c.c. per minute *up to a quantity restoring the normal blood volume.* Certain circumstances should be remembered in which excessive transfusion may be a real danger. *Firstly*, intravenous saline and glucose-saline administrations may not be retained in the circulation, and with excessive infusion of these fluids, pulmonary oedema may ensue. This type of infusion, however, is seldom needed in "shock". If, for any reason, the patient is dehydrated, e.g. from excessive vomiting after an abdominal injury, it is useful to remember that a drip infusion of saline at the rate of 40 drops per minute supplies a pint of fluid in 4 hours, which is quite a suitable rate in the average case. *Secondly*, in the stage of post-haemorrhagic anaemia which may be reached a day or two after acute blood loss, the circulation is not normal. It has already been mentioned that in such cases the pulse is full and bounding, often 90–100 per minute and with a high pulse pressure (e.g. 120/50 mm. Hg). In such anaemic subjects, the cardiac output is often doubled. Large rapid transfusions may precipitate pulmonary oedema from heart failure in these cases. Preparation of such patients for operation is best carried out by small transfusions (one bottle) of concentrated blood corpuscles (see Appendix E), or one or two bottles of whole blood, in either case given *slowly* by a drip method. *Thirdly*, severe burns may be complicated by thermal trauma of the lungs and air passages. Pulmonary oedema is liable to complicate transfusion in such cases, and also in patients who have suffered blast injury of the lungs or have pulmonary fat embolism. A similar risk is present in certain types of gas poisoning, as already noted (p. 10).

Excessive amounts of serum dilute the blood unduly and render the patient anaemic. This applies also in burns.

Oxygen Administration

On the hypothesis that the slow circulation in "shock" led to tissue anoxia, it was hoped that giving pure oxygen by a B.L.B. mask would lead to improvement. These expectations have not been borne out, either in experiment or in practice. In the absence of good evidence of its efficacy, it seems unwise to recommend

this measure in addition to transfusion. Oxygen therapy should, therefore, be relegated to its appropriate place—e.g. when injury to the chest has led to interference with respiratory oxygen uptake, or where there is pulmonary oedema. The administration of oxygen plays an important part in the treatment of casualties due to pulmonary irritants. The technique is discussed in the *Medical Manual of Chemical Warfare.* The B.L.B. mask* is particularly useful in the treatment of carbon monoxide poisoning, especially as rebreathing from the bag brings about an advantageous increase in the percentage of CO_2 in the lung alveoli, as well as a high concentration of oxygen.

Anaesthesia

(a) *Indications for operation.*—In general, operation will be undertaken as soon as possible after resuscitation has brought the systolic blood pressure up to 100 mm. Hg or higher. Exception may have to be made in cases with persistent haemorrhage, with open chest wounds or with severe laceration, where recovery is thought unlikely without active surgical intervention. In these cases, operation should not be delayed pending improvement in the patient's condition but should be undertaken at once, a transfusion being given during the operation.

(b) *Premedication.*—Atropine gr. $\frac{1}{150}$ or scopolamine gr. $\frac{1}{200}$ are best injected intravenously in the anaesthetic room after final assessment of the patient's condition, with or without morphine according to the degree of respiratory depression.

(c) *Choice of anaesthetics.*—Spinal analgesia is contraindicated. Chloroform should be avoided where possible. Ether may be given, preferably as an adjuvant to nitrous oxide, in minimal quantities. The dose can be better regulated with the Oxford vapouriser than with an open mask. Nitrous oxide is suitable, provided that not less than 20 per cent. of oxygen is given. Anaesthesia must be deepened, if necessary, by supplementary anaesthetics—not by reducing the percentage of oxygen. Cyclopropane is excellent in the hands of those skilled in its use. Pentothal and hexobarbitone are also suitable and convenient, *but with all anaesthetic agents, especially the intravenous barbiturates, it is essential to remember that susceptibility is greatly increased in " shock ".* A closed technique with *efficient* carbon dioxide absorption is the method of choice.

(d) *Maintenance of anaesthesia.*—Skilful administration is of much greater importance than the actual choice of anaesthetic drug. An apprehensive patient may be given 3 c.c. of pentothal to ensure smooth induction of inhalation anaesthesia. On no account should the airway be allowed to become obstructed. A look out should be kept for the possibility of vomiting, especially under light inhalation anaesthesia, and, when it occurs, immediate steps should be taken to clear the airway. Tracheal intubation is necessary if the airway cannot be kept clear by other means. Such an accident as temporary laryngeal obstruction, often regarded as trivial, may suffice to tip the scales against the recovery of a " shocked " patient.

Anaesthesia, with whatever drug, should be maintained at as light a level as is consistent with the provision of satisfactory operating conditions. Where muscular relaxation is needed, as in abdominal operations, this should be obtained by the use of local anaesthetics—$\frac{1}{2}$ per cent. procaine, 1/3000 nupercaine or amethocaine. Use may also be made of local anaesthetics in operations involving severe trauma, such as manipulation of a fractured femur, before section of large nerve trunks and before disarticulation of the hip joint. Such traumata may cause a severe fall in blood pressure even in fit subjects.

---

* For further details, see also E.M.S. Memorandum No. 5, Revised (1944) " Oxygen Administration—Indications, Methods and Types of Apparatus ".

(e) *Handling of the patient.*—The anaesthetist must supervise, personally, any movement of the patient on the operating table, which must be as gentle as possible and restricted to the essential minimum. He is also responsible for seeing that the patient is kept adequately covered for the temperature of the theatre. He will, if necessary, call attention to the importance of covering exposed bowel or large raw areas as far as possible with packs wrung out of warm saline.

(f) *Oxygen.*—In patients suffering from or recently recovered from " shock ", not less than 20 per cent. of oxygen should be given in the mixture, and this may be raised to 30 per cent. or more where anaemia or respiratory depression is present. *In pallid patients, anoxia may be present without cyanosis of the skin, though this may show in the mucous membranes.* If respiration is depressed, not more than 5 per cent. of carbon dioxide may be added. If there is no improvement in general condition within 10 minutes, this should be discontinued. Nikethamide 1 c.c. may be injected intravenously, to stimulate respiration. Oxygen should be given with " open ether " or with intravenous pentothal.

(g) *Resuscitation measures.*—The anaesthetist may be responsible for the maintenance of the patient's condition during the operation. An intravenous drip should be set up at the beginning of any operation on a " shocked " patient, to avoid unnecessary delay in the event of sudden collapse.

Repeated blood pressure and pulse records must be kept wherever possible, and the patient closely watched for the development or increase of pallor, coldness, sweating or delayed capillary return (in forehead or chest). If there is any further haemorrhage after the establishment of anaesthesia, the rate of drip must be increased. If a fall in blood pressure is due to manipulation of injured limbs or gut, a short pause in the operation is usually all that is required. If the fall persists, the effect of speeding up the transfusion may be tried, but it is not advisable to pursue transfusion beyond the amount judged sufficient to restore blood volume (especially in belly cases).

Where the systolic blood pressure has fallen below 80 mm. Hg and no satisfactory response can be obtained to resuscitation measures, the anaesthetist must warn the surgeon, so that any less urgent part of the operation may be postponed.

(h) *After-care.*—The anaesthetist will see that the patient's airway is clear before leaving the theatre, and that the attendant is properly instructed. The anaesthetist will report on the patient's condition to the resuscitation team. If the patient has had a high proportion of oxygen during anaesthesia, this should be continued during the journey back, and after return to the ward.

Treatment of Complicating Conditions

Vasovagal collapse.—This condition may vary in significance from an ordinary emotional faint to a manifestation of severe haemorrhage. A decision on its severity can, therefore, be made only by full clinical observation. The patient should be put at least in the recumbent if not in the head-down position. If he recovers rapidly, nothing further may be required. If he remains in a state of vasovagal collapse unduly long—say 20 minutes or more—active measures may be needed. Transfusion will rapidly restore the circulatory state to normal. Vasoconstrictor drugs have a place in treatment. N-methyl amphetamine (methedrine), 15 mgm. intramuscularly or intravenously, is worth trial, as it may restore the blood pressure to normal in a vasovagal faint after bleeding.

After the blood pressure has recovered, such patients should be carefully watched. Any further blood loss or operation may be followed by a repetition of a similar type of disturbance or by the more usual picture of oligaemic " shock ".

Tissue trauma.—It has already been emphasised that severely traumatised tissue should be removed at the earliest possible moment. It has been shown that delay in performing primary operation leads to a steep rise in mortality.

Post-traumatic hypertension calls for no special treatment. The picture may, however, change later on to that characteristic of oligaemic " shock ".

Burns.—Morphine should be given to patients with extensive burns, to relieve pain, anxiety and restlessness, and to reduce the excessive sensory stimuli which may contribute to shock ; it is best given intravenously (see p. 13). A comfortable but not excessive degree of warmth should be provided by blankets, and if necessary by hot water bottles. Blankets used to wrap the burned patient should, where possible, be *sterilised*, since the risk of infection of a newly burnt area is very great.

Loss of fluid from the circulation may be counteracted in one of three ways :—

(*a*) It can probably (but not certainly) be restrained by the efficient use of some form of *pressure dressing*, applied, if possible, within 1–2 hours of burning, though later applications may also help. Whatever the nature of this dressing, it must be applied with skill and discretion, otherwise it may obstruct the circulation. Elevation of burned limbs (especially the hand and forearm), well above the level of the heart, is very useful in lessening oedema.

(*b*) *By the administration of fluids by the mouth.*—Warm drinks should be given in so far as the patient is able to take them, but there is a tendency in " burns shock " for the patient to vomit if more than small amounts are administered at a time. On the basis of experimental work indicating that the sodium ion plays a special part in recovery from shock, the administration of large amounts of isotonic sodium lactate solution (2 per cent.) by mouth has been recommended, but its value has not yet been adequately assessed.

(*c*) *By early and adequate transfusion of serum or plasma*, especially where the burn exceeds 20 per cent. of the body surface. Serum or plasma is preferable to whole blood for patients with burns. For a severe burn, a drip transfusion should be set up before the injury itself is attended to, and it should be kept going for 24 hours—sometimes a little longer. The amount of intravenous fluid required cannot always be gauged satisfactorily by any of the existing formulae based on blood examinations, since the patient may have been anaemic before injury ; further, it is impossible to determine how much of the transfused fluid will leak out of the circulation. The practice of giving one pint of plasma for every 10 per cent. of the body surface burned has its advocates, but some observers believe it necessary to use larger amounts on occasion. The size of the patient and the extent of the burn give an approximate indication of the amount of fluid required, but the best guide is provided by the degree of haemoconcentration and its response to therapy. In adults with extensive burns, as much as 7 or 8 litres of plasma or serum in the first 30 hours have sometimes been required to correct haemoconcentration, *but the giving of such large amounts demands constant watchfulness*, particularly when the face has been burned, and when hot air, flame or steam may have been inhaled. It is not difficult—especially in children— to induce a fatal pulmonary oedema by giving intravenous fluid too fast or in too large an amount. The speed of transfusion should be determined by circumstances and guided by the blood tests mentioned. Thus, a severely burned adult, admitted

after several hours, with well developed haemoconcentration, should be transfused with the first pint in 10–15 min., the second in 20–30 min., and then more slowly. In a child with a moderate burn and less pronounced haemoconcentration, such a speed would probably be excessive. When pressure dressings can be applied satisfactorily, it is likely that smaller amounts of fluid will be required for transfusion. It is usually unnecessary to continue giving serum or plasma for more than 30 hours after burning.

In transfusing burned patients, strict asepsis is essential or thrombophlebitis is liable to ensue. In quiet and cooperative patients, an intravenous needle may be satisfactory, but in the early critical period, a cannula is often necessary owing to restlessness. Where both arm veins are burned, the leg veins or the external jugular vein may be used, though some workers have found that spasm of the former adds to the difficulties. In certain circumstances, sternal transfusion may be advisable, but this also requires great care.

Crushing injuries.—Patients who have been trapped for one hour or more beneath debris should be considered as possible cases of crush syndrome, and hence likely to develop signs of renal failure. When casualties from an incident are brought to hospital much later than the first arrivals, special enquiry should be made whether the delay may have been due to trapping.

Renal damage due to substances absorbed from the necrotic muscle is probably produced as soon as the circulation to the damaged part is re-established, although it is often not clinically noticeable until some days later. Once established, renal failure is very difficult to treat.

It is, therefore, considered that steps to *prevent* the development of renal failure should be taken at the earliest possible moment. The main essential is to establish diuresis. Although final agreement has not been reached, it is possible that precipitation of myohaemoglobin as acid haematin in the tubules may play some part in the production of both the " crush " kidney and the " mismatched transfusion " kidney. Since such precipitation does not occur in dilute alkaline urine, the giving of fluids and alkali has been advocated in both these conditions. It must be emphasized, however, that this and all other forms of preventive treatment are still not fully evaluated, and that cases must be very carefully studied if any therapeutic conclusions about them are to be drawn.

(a) *Administration of fluid and alkali.*—Instructions have been issued to Civil Defence personnel to give sodium bicarbonate by mouth and fluids such as tea, coffee or water, if possible before release from compression, to patients buried more than one hour. Patients so treated should wear an identifying label and must be followed with special care. Some cases may not have had this alkali and fluid before they enter hospital. All cases should be given sodium bicarbonate, 7gm. (2 oz.) hourly by mouth until the urine turns red litmus blue, but not for longer than 24 hrs.

Should vomiting preclude oral administration, of if it is desired to alkalinise the urine rapidly, one litre of isotonic ($\frac{M}{6}$) sodium lactate solution (2 gm. per 100 c.c.) should be given intravenously. If sodium lactate is not available, 3–4 per cent. sodium citrate may be used in *limited* amounts. It has the disadvantage that large quantities, or too rapid injections, produce tetany. One pint only, therefore, should be used, as a stop gap until a more suitable alkali can be obtained. Sodium bicarbonate (1·4 gm. per 100 c.c.) also can be given intravenously, but as it decomposes on heating, sterilisation is difficult; in an emergency, two teaspoonfuls may be dissolved in a pint of sterile water and injected without sterilisation. It must be emphasised that this alkalinisation, to be effective, should be early and thorough, the criterion of its efficacy being the reaction of the urine. If possible, it should precede measures taken to improve the circulation through the injured part.

A measured fluid intake of at least three litres daily should be assured either by mouth or by vein. The daily volume of the urine should be measured. If haemoconcentration is present, serum or plasma transfusion should be given *without waiting until the blood pressure falls.*

(b) *Local treatment.*—The injured limb should be kept cool by evaporation of wet compresses if the circulation is imperilled, and be immobilised for the first few days. Operative interference may be required for circulatory obstruction. Amputation should be done only if the leg is so severely damaged as to be useless, and then in the first 24 hours.

(c) *The treatment of established renal damage.*—The treatment of established renal damage should be along the lines adopted in mismatched transfusion; diuretics such as intravenous sodium sulphate (4·3 gm. per 100 c.c.) may be of value. Decapsulation has also been suggested, as well as hot packs to the loins and spinal anaesthesia. It is difficult to evaluate these therapeutic measures, as sometimes patients with a high degree of uraemia (500 mgm. urea per 100 c.c.) recover spontaneously without any form of treatment.

Fat embolism.—Complete immobilisation of the injured parts, rest and morphine, may help to prevent this condition. The developed condition may not be fatal. No effective treatment is known.

CO poisoning.—Treatment has already been mentioned, under oxygen therapy (p 16.)

Post-operative hypotension.—Operations are often followed by a considerable fall in blood pressure, e.g. to 70 mm. Hg, which probably results from vaso-dilatation induced by anaesthetics, and is perhaps contributed to by sensory stimuli. Lengthy operations also contribute. Patients usually recover well without transfusion. N-methyl amphetamine (15 mgm. intravenously) has been reported as of considerable value in this common clinical type of hypotension.

APPENDIX A

THE ARMY BLOOD TRANSFUSION OUTFITS AND INSTRUCTIONS

(1) Instructions for Using the Overseas Pattern of Transfusion Equipment for the Administration of Blood or Plasma

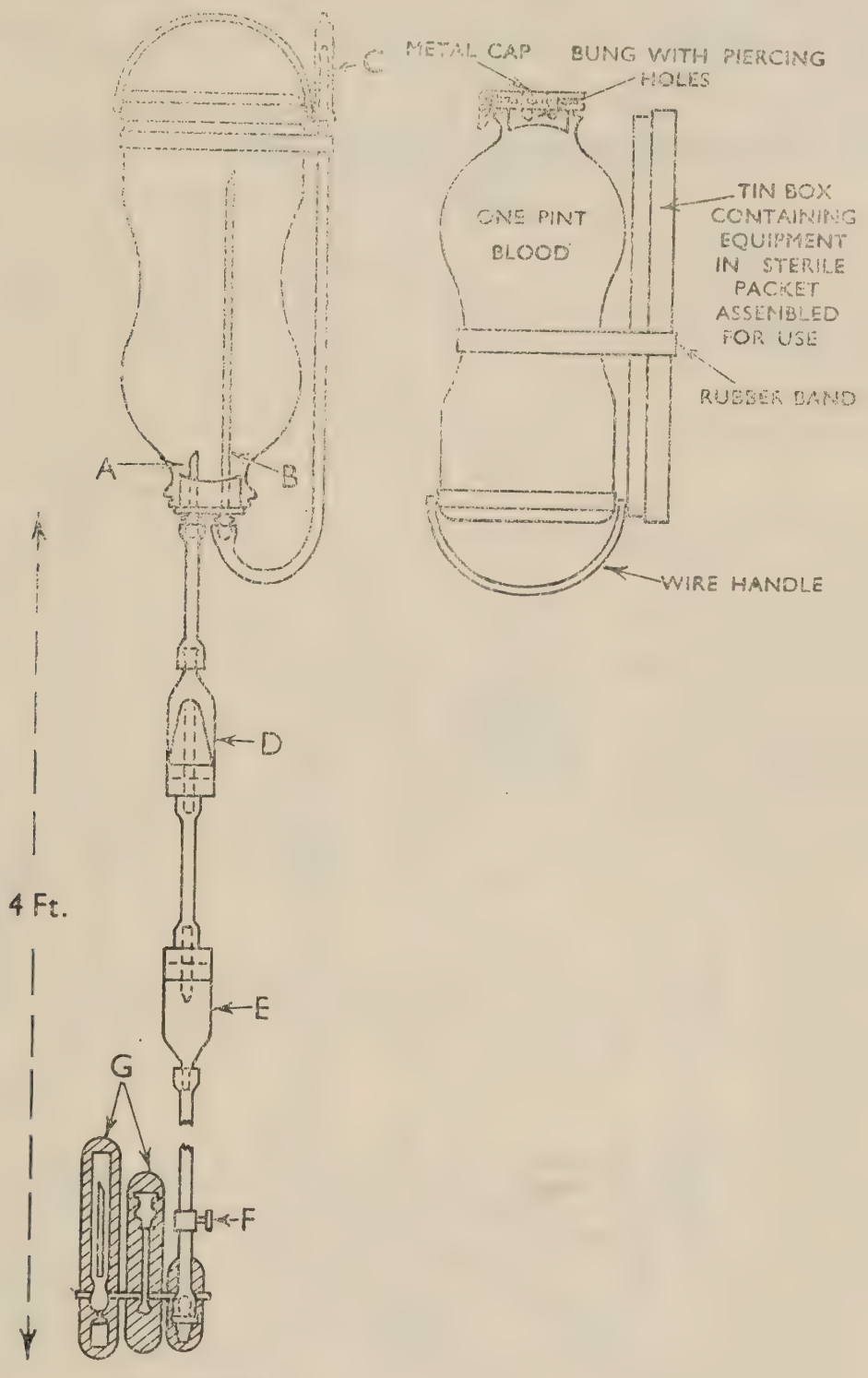
The equipment consists of blood (Universal Donor), or of plasma, in a pint bottle to which is attached, by a rubber band, a tin box containing the sterilised apparatus for administration (see Fig. 1).

Blood

The blood should be thoroughly mixed by inverting and rotating the bottle. The metal cap is then released and the temperature of the blood raised by standing the bottle in water at 40° C. (104° F.) for about 15 minutes. It is important to release the metal cap first, otherwise the bottle may break. Open the tin box and unwrap the "Cellophane" packet. Plunge the short piercing tube A through one of the holes in the bung and follow with the long piercing tube B through the other hole. Fix the air inlet C to the base of the bottle with the rubber band, invert the bottle and hang it up by means of the wire handle. The blood may then be observed flowing through the filter D and the drip counter E; as soon as it appears at the wrapped end of the tubing, close screw clamp F. Slight pressure through air inlet C (which contains a non-return valve) may be necessary to start the flow of blood. Two small packets G are attached near the end of the rubber tubing. One packet contains a sterile needle protected by a glass tube, together with an adaptor to fit the Army pattern syringe; the other contains a stainless steel cannula for cases in which it is necessary to cut down on a vein. Attach the needle to a syringe by means of the adaptor and prove entry into the vein. Remove the syringe and adaptor, leaving the needle in the vein, and attach the tubing to the needle. Unscrew clamp F and allow the blood to flow into the vein.

Approximately 15 minutes is required to empty the bottle, using the needle supplied, and the full head of 4 ft. provided. If necessary, pressure may be applied through the air inlet C, either by blowing down it or with a Higginson's syringe.

Each crate of ten bottles is labelled with the date beyond which it is unwise to use the blood. When the supernatant plasma is tinged red, the blood should not be used.



EQUIPMENT ASSEMBLED FOR USE

A SHORT PIERCING TUBE

B LONG PIERCING TUBE

C AIR INLET CONTAINING NON-RETURN VALVE ENABLING PRESSURE TO BE APPLIED

D MANTLE FILTER

E DRIP COUNTER

F SCREW CLIP

G TWO PACKETS. ONE CONTAINING NEEDLE AND SYRINGE ADAPTOR THE OTHER A CANNULA

FIG. 1. **Army Giving Set.** Overseas pattern for use with fluid plasma or blood.

A record of the success or otherwise of the transfusion should be entered on the numbered card attached to each bottle, and the card posted. This information is essential for the regulation of future supplies.

All used equipment should be returned to the officer in charge of the refrigerator unit issuing the blood.

Plasma (See Appendix C, p. 28)

(2) Blood Transfusion Equipment for the Taking, Storing and Giving of Blood in Military Hospitals

The equipment consists of a moulded glass bottle (capacity 560 c.c. or approximately one pint), fitted at the base with a wire handle, and two calico packets containing the requisite bungs, tubing and needles. With first issues, all apparatus is sterile and ready for use. Taking (and giving) sets, each wrapped in a calico envelope, are issued in tins each containing six sets. Test tubes of glass beads to act as a filter are included with the giving sets. (Fig. 2.)

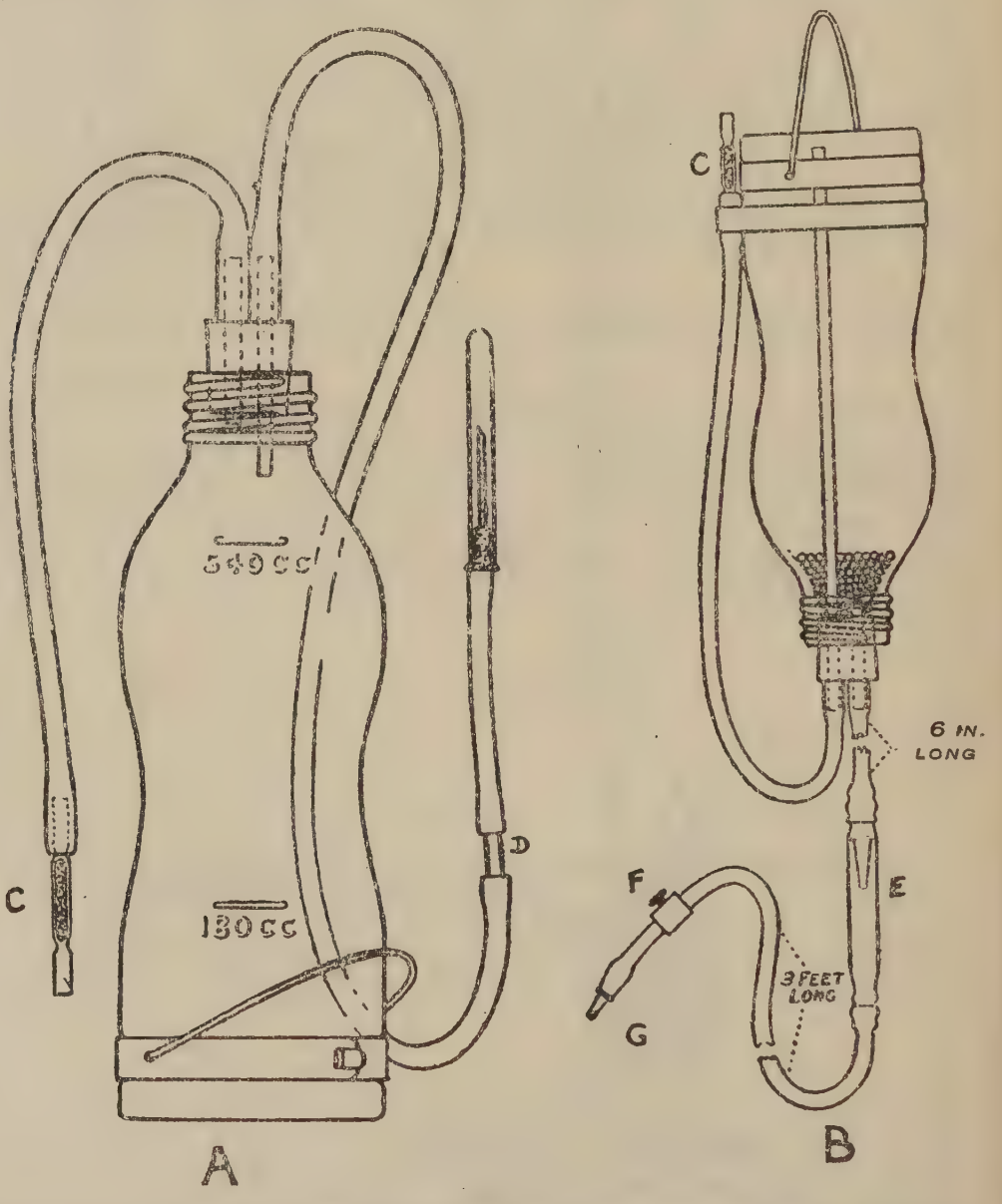


FIG. 2.

A. Army Universal Pattern Taking Set. C = Air filter : D = Glass window.

B. Army Giving Set, Hospital Pattern. C = Air filter : E = Drip counter : F = Speed regulator : G = Tubing mount.

The apparatus can be used either for the administration of glucose and saline solution, or for the taking and giving of *fresh blood* obtained from local donors ; it can be dismantled, cleaned, reassembled and used again.

Sterilisation

When resterilisation is necessary, the cleaned "taking" and "giving" sets, each wrapped in its calico bag and complete with needle, are repacked in the tin boxes. Three plugged tubes of glass beads should be packed in each box containing "giving" sets (6). Sterilisation of the tin box with contents is carried out in the autoclave (15 lb. for 20 minutes). When complete, the lid of the tin is replaced and sealed down with adhesive tape.

Empty screw cap B.T. bottles for the collection of blood should be carefully washed and dried. Sterilisation should be carried out with the screw caps loosened. These should be tightened when the bottles are removed from the autoclave. (See also Appendix D, p. 31.)

Care and Maintenance

After use, more especially with blood, the apparatus should be immersed immediately in cold water, to prevent drying. Subsequently the apparatus must be completely dismantled and thoroughly cleaned in cold running water. The bore of the thick taking tubing is easily cleaned by means of the pull-through brush, but the thin giving tubing does not survive repeated autoclaving, is difficult to clean, and once used with blood cannot always be used a second time. The glass tubing is easily cleaned with a pipe cleaner. Lack of cleanliness, especially the presence of small fragments of clot, is a fruitful source of reactions. Beads must be cleaned at once. (See also Appendix D.)

Directions for Use

Taking Blood

Remove the screw cap from an empty sterile B.T. bottle and quickly add the anticoagulant solution, consisting of 2 gm. disodium citrate and 3 gm. glucose dissolved in 120 c.c. water. Replace the cap. Remove a sterile taking set from its bag, remove the cap and quickly insert the bung firmly in the bottle. If it is proposed to store the blood all these manœuvres ought to be carried out near a flame as in bacteriological work, but if the blood is to be used fresh, such precautions are unnecessary. Remove the protecting tube from the needle and the apparatus is ready for use. (Fig. 2A.)

Congest the veins of the donor's arm by means of a tourniquet or sphygmomanometer armlet, raised to a pressure of 60–80 mm. Hg. Raise an intradermal wheal with a local anaesthetic over the selected vein and pass the transfusion needle through the anaesthetised area into the lumen of the vein, whereupon blood will appear in the glass window of the tubing. Fix the needle with one hand, and with the other lower the bottle to the extent of the tubing, maintaining a slow rotary motion to mix the blood and citrate solution. The donor should clench and unclench the fist in order to assist the flow of blood. Negative pressure may be applied by means of the mouthpiece, but this should be unnecessary. With a good donor it is possible to fill the bottle in 5 minutes. When the bottle is filled to the upper mark, release the tourniquet, withdraw the needle, and raise the tubing to allow all the blood to flow into the bottle. Cover the puncture wound with a sterile swab and instruct the donor to keep the elbow fully flexed for 15 minutes. The donor should lie quietly on a stretcher for half an hour and be given a drink of warm sweet tea. After this time he may return to duty.

Storing Blood

If the blood is not to be used at once the " taking " bung should be removed from the bottle and the sterile screw cap substituted. This change should be carried out near a flame. The blood should then be placed in a refrigerator at a temperature 4° to 6° C. Freezing of the blood must be avoided. Stored blood which is haemolysed must not be used. (See also p. 28.)

Giving Blood

It is necessary first to add about 20 c.c. (an ordinary test tube full) of beads to the bottle, and secondly to replace either the " taking " bung (if the blood is used immediately after taking) or the screw cap (if the blood has been stored) with the bung of the sterilised " giving " set. Either remove the " taking " bung assembly and place this at once in cold water or, after warming up the bottle, remove the screw cap, and at once add the beads and then substitute the bung of the sterilised " giving " set. (Fig. 2B.) *This should always be fixed securely in the bottle with strapping.* Attach the air inlet tube to the base of the bottle or tape and then invert the bottle and hang it up on a suitable stand. On inverting the bottle, the beads will collect in the neck and form an efficient filter for the blood, which will pass down the tubing and through the drip counter and so to the needle mount, whereupon the screw clamp should be closed. By means of the adaptor attach the transfusion needle to a small record syringe and insert into the selected vein. When the needle is in position detach the syringe and adaptor and attach the tubing by means of the tapered mount. The screw clamp is then released to allow a suitable rate of flow as seen in the drip counter. If necessary, positive pressure may be applied to the air inlet tube by attaching a Higginson's syringe. If the glass bead filter appears to be clogged, a gentle rotation of the bottle will usually re-establish patency.

APPENDIX B

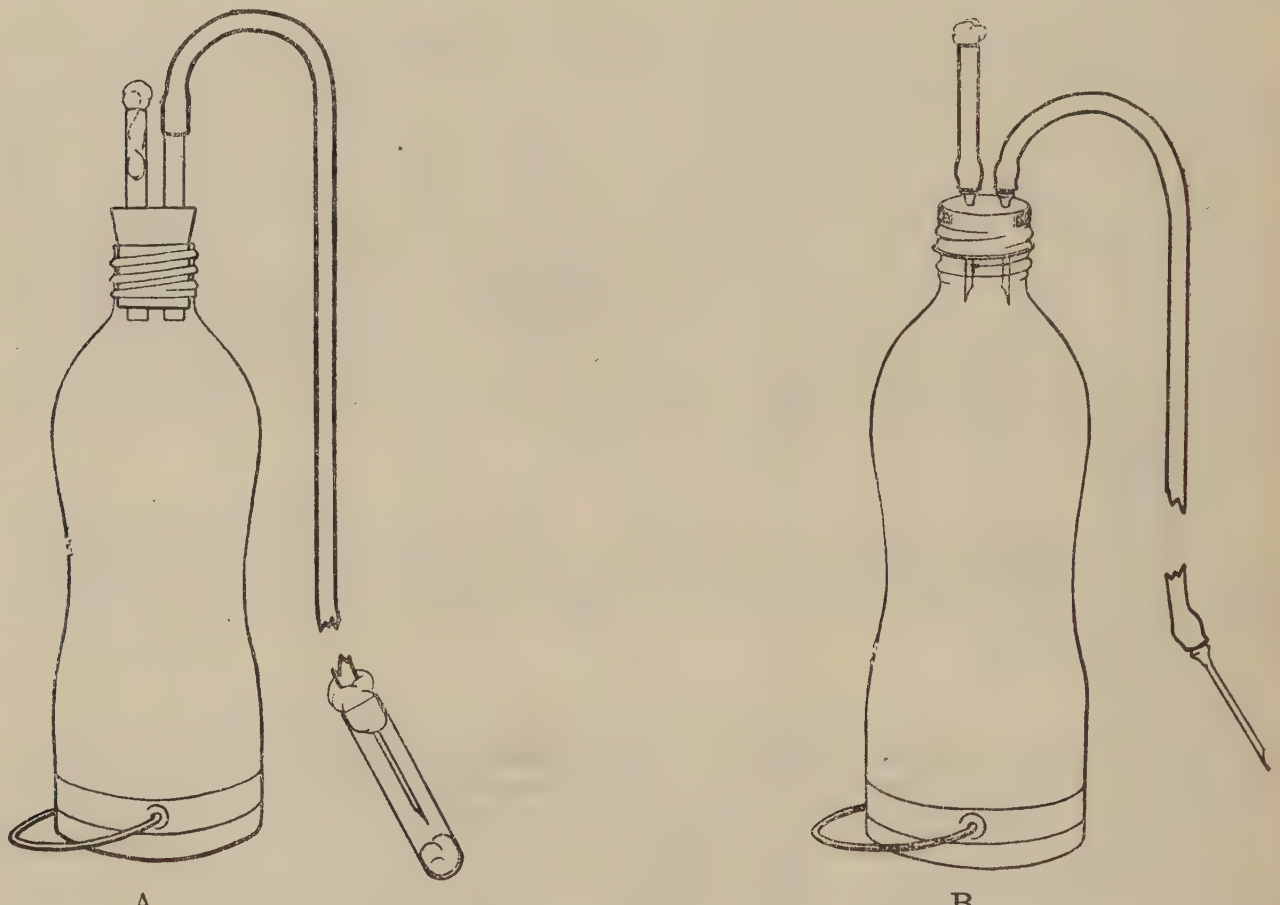
The Medical Research Council Blood Transfusion Outfit

(as provided for the London Depots and the Ministry of Health Regional Transfusion Centres)

The following are now available for transfusion in standard Medical Research Council bottles :—

(i) Stored blood.
(ii) Blood products—
  (*a*) liquid serum or plasma ;
  (*b*) dried serum or plasma for reconstitution.

Serum is separated from blood which has been allowed to clot. It, therefore, contains no fibrinogen. Plasma is prepared from citrated blood which does *not* clot and, therefore, contains fibrinogen.* The protein content of a bottle of serum is higher than that of plasma, being in the neighbourhood of 7 per cent ; the protein content of plasma, owing to the added diluent, is about 4·5 per cent. Both plasma and serum, after separation, are Seitz filtered and, if drying is to be carried out, this is done from the frozen state.



A B

FIG. 3. The Two Types of Medical Research Council Taking Unit.

The Medical Research Council bottle for the taking, storing and giving of blood or blood products is a modified pint milk bottle, slightly waisted to facilitate holding, fitted with an aluminium screw cap with a 4-mm. rubber liner inset, and provided with a metal band and loop at the base for hanging the bottle in the inverted position.

Fig. 3A shows the bottle with the screw cap removed and replaced by a rubber bung and glass tubing.

Anticoagulant

Two different anticoagulant solutions are at present employed :—

(1) Trisodium citrate solution containing glucose.
(2) Disodium hydrogen citrate solution containing glucose.

(1) *Trisodium citrate solution containing glucose.*—This anticoagulant solution consists of 100 c.c. of 3 per cent. trisodium citrate in distilled water, to which are added 20 c.c. of 15 per cent. glucose in distilled water. The citrate and glucose must be of a high grade of purity, and freshly distilled water is used for making up the solutions, which are filtered

---

* This fibrinogen, together with the prothrombin, may be subsequently removed by certain technical procedures, involving the use of kaolin.

and autoclaved immediately. Glucose tends to caramelize during autoclaving in the presence of citrate ; it is, therefore, necessary to sterilise the citrate and glucose solutions separately, and to mix after sterilization ; 120 c.c. of anticoagulant solution are used* for 420 c.c. of blood, making a total volume of 540 c.c. (approximately 1 pint).

(2) *Disodium hydrogen citrate solution containing glucose.*—Red cell preservation is most satisfactory when small amounts of disodium citrate are used, but clotting is then likely to occur unless brisk shaking is maintained throughout the period of blood collection. Solution (*a*) below is the better preservative. Solution (*b*) should be used when it is impossible to ensure constant shaking throughout the collection.

(*a*) This solution consists of 1·66 per cent. disodium citrate and 2·5 per cent. glucose ; it is prepared by taking 2 gm. disodium hydrogen citrate and 3 gm. glucose, and making up to 120 c.c. with distilled water.

(*b*) This solution consists of 2·08 per cent. disodium citrate and 2·5 per cent. glucose ; it is prepared by taking 2·5 gm. disodium hydrogen citrate and 3 gm. glucose, and making up to 120 c.c. with distilled water.

Both mixtures can be autoclaved with the production of a negligible amount of caramel, the amount varying with the quality of the glucose and with the duration and temperature of autoclaving.

Withdrawal of Blood

Two types of apparatus for blood withdrawal are in common use. These involve either :—

(i) Replacement of the cap by a rubber bung and glass tubing.

(ii) Perforation of the cap by two needles.

(i) *Replacement of the cap by a rubber bung and glass tubing.*—The screw cap of the Medical Research Council bottle is removed and kept sterile. The bottle is then fitted with a sterile " taking set," comprising a rubber bung pierced by two 3-inch glass tubes, one of which is lightly plugged with cotton wool and acts as an air vent. To the other, is attached a length of rubber tubing and a stainless steel needle (Fig. 3A), which is protected by a small glass test-tube or short length of rubber tubing plugged with cotton wool. The glass tube only is shown in the diagram, for reasons of clarity.) A short length of glass tubing may be inserted just before the needle, to serve as a window, so that the passage of blood down the tube may show the operator he has entered the vein. A sphygmomanometer cuff or tourniquet is applied to the upper arm of the donor, and the skin over the vein in the anticubital fossa cleaned, first by rubbing well with ether soap and water applied by a sterile swab, and then by two further swabbings with phenylmercuric acetate in 70 per cent. alcohol. The cuff is inflated to a pressure of 80 mm. Hg, at which level the pressure is maintained, and approximately 0·1 c.c. of a local anaesthetic is introduced intradermally over the vein. The needle of the taking set, after removal of the protecting tubing or glass, is then inserted into the vein, and held in position while the bottle fills. Gravity should be sufficient to maintain a steady flow of blood. This may be facilitated by asking the donor to open and close his hand. It is essential to mix the blood and anticoagulant, by gentle rotation throughout the collection. Frothing should be avoided by allowing the blood to flow down the side of the bottle rather than straight into the anticoagulant. The blood having been withdrawn, and the rubber bung with its tubing removed, the bottle is again sealed by the screw cap, after its neck has been flamed. Samples for a re-group and a Wassermann or Kahn test may be obtained from the end of the rubber tubing after removal.

(ii) *Perforation of the cap by two needles.*—In this method, the aluminium cap of the blood bottle is perforated, by machine, with two holes 3 mm. in diameter. These are sealed after the bottles have been autoclaved, with either a viscose cap or a strip of adhesive tape. Immediately before blood withdrawal, the perforations are exposed by removal of the viscose cap or adhesive tape. Through one hole in the cap is pushed a taking (or administering) needle, to which is attached a short length of rubber tubing plugged with cotton wool ; through the second hole is pushed a taking needle to which is attached a longer piece of rubber tubing carrying a second taking needle at the other end (protected by a short piece of tubing), for insertion into the vein. Both needles inserted into the cap are pushed through the rubber diaphragm (Fig. 3B). After removal of the blood as described with apparatus (i), the needles are withdrawn from the aluminium cap and the holes sealed with a fresh strip of adhesive tape. Samples for a regroup and a Wassermann or Kahn test may be obtained from the end of the rubber tubing after its removal.

The Administering Unit (Fig. 4)

This consists of a rubber bung pierced by two glass tubes, one of which is 9½ inches long and reaches almost to the bottom of the bottle, being closed externally by a small cork. The other tube is 2½ inches long ; it is covered by a metal gauze filter or gas-mantle

---

* The bottle is marked at 180 c.c. and 540 c.c. The volume of anticoagulant originally used was 180 c.c., but this has now been changed. The mark at 180 c.c. is thus no longer relevant.

filter, and has attached to its outer end, in sequence, a length of rubber tubing, a drip feed, a further length of rubber tubing ending in a male metal adaptor, a female adaptor with a " Record " fitting, a short piece of rubber tubing and a narrow bore stainless steel needle protected by a small test-tube or piece of rubber tubing.* A screw clip is attached to the rubber tubing just above the male adaptor. A metal cannula attached to a short piece of rubber tubing and a female adaptor may be used instead of the needle when it is necessary to cut down on a vein. If desired, the rubber tubing may be omitted and the cannula be attached directly to the male adaptor.

The Wire-gauze Filter

The wire gauze filter consists of a cylinder of close-meshed stainless steel gauze, one end of which is open, the other partially closed by folding back the wire so as to leave a small hole for the passage of the 9½-in. length of glass tubing. The gauze filter is fitted on to the 9½-in. length of glass tubing, by pushing it up till the open end is pressed firmly against the rubber bung covering the open end of the 2½-in. glass tube. A small ring of rubber tubing is then rolled up the 9½-in. glass tubing until it comes into contact with the other end of the filter (Fig. 4). This end, which is already partially occluded, should then be firmly closed by applying pressure with artery forceps.

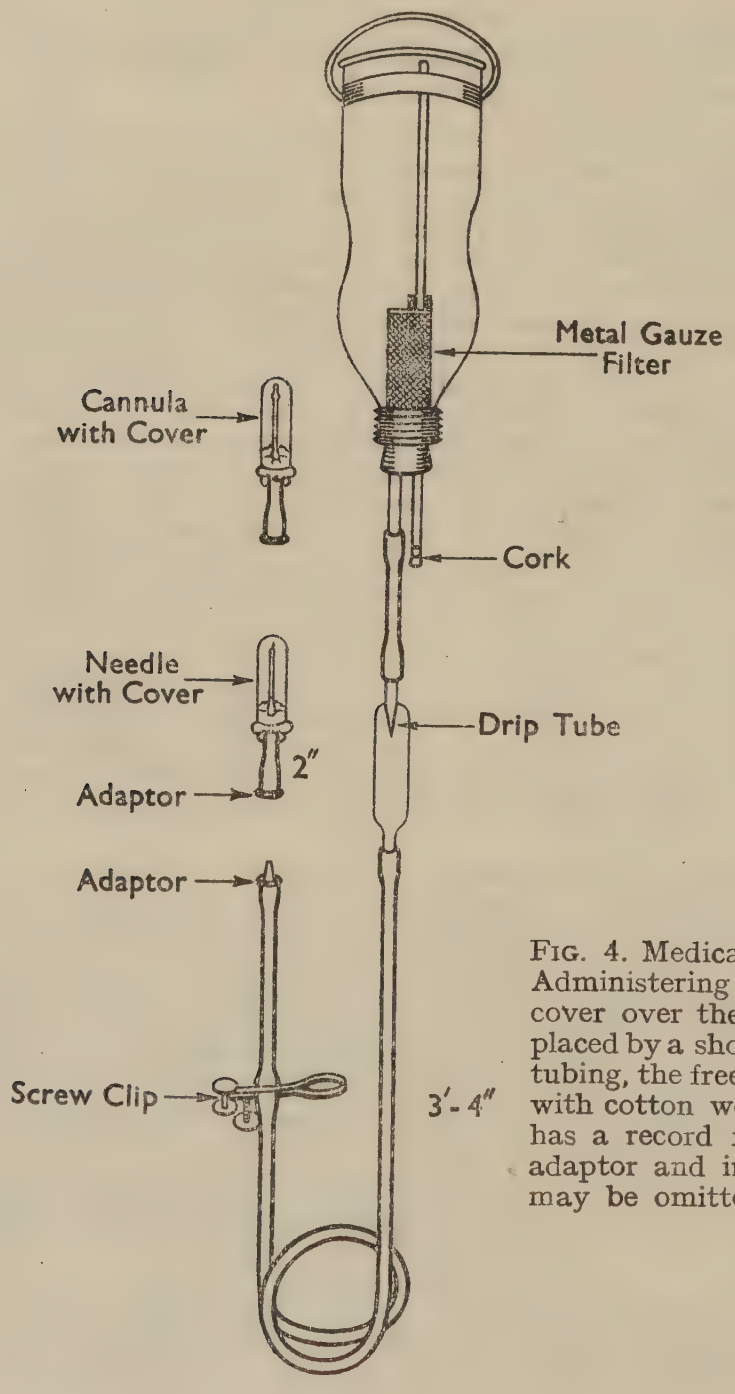


FIG. 4. Medical Research Council Administering Unit. The glass cover over the needle can be replaced by a short length of rubber tubing, the free end being plugged with cotton wool. If the needle has a record fitting, the female adaptor and intermediate tubing may be omitted.

* In Scotland, the needle has a record fitting which engages directly into the male adaptor, and the short piece of rubber tubing and female adaptor is not included in the unit.

The Gas-mantle Filter

This type of filter consists of an open cylindrical stocking of finely knitted cotton, as used in the manufacture of gas-mantles. It is 3½-in. long, and is supplied by the makers threaded with a purse string at each end. The filter is supported inside the bottle by a ¼-in. piece of thick pressure tubing, which is pushed on to the long glass tube of the delivery set until it is about 2½-in. from the narrow end of the bung (Fig. 5). The stocking is slipped over the bung and the long tube; one end is fastened securely by tying its purse string beyond the pressure tubing, the other is fitted round the inner end of the bung (Fig. 5), where it should be fixed by fine copper wire (Fig. 5) or by grooving the neck of the bung so that the purse string can be tied tightly. In this way, the stocking is pulled into a stretched closed cone over the inner end of the delivery tube.

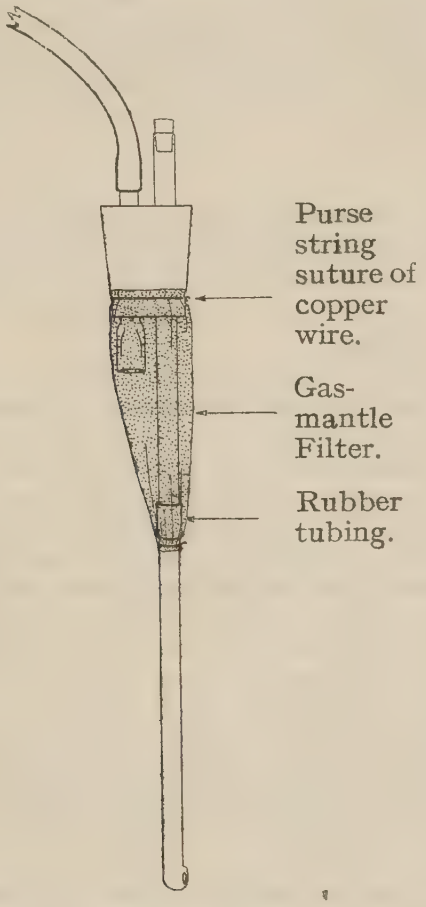


FIG. 5. Gas-Mantle Filter.

Drip Feeds

The routine issue is the simple drip feed shown in Fig. 4.

APPENDIX C

The Storage, Preparation and Administration of Blood or Blood Products

Storage

Blood

Blood should be stored at a steady temperature between 2° and 6° C. It must on no account be allowed to freeze. It should be noted that the temperature often varies widely in different parts of a refrigerator. With anticoagulant (1) blood may be used up to 14 days of storage ; with anticoagulant (2) blood may be used up to 21 days of storage.

Liquid serum or plasma

Liquid serum or plasma should be stored in the dark in a cool place—refrigeration is not necessary. These are not stable products, and should be shaken and moved from place to place as little as possible. Before use, they should be held up to the light and if there is any flaking or precipitate the bottle should be discarded, as it is impossible to distinguish by naked eye examination between a bacterial growth and a harmless precipitate. Such a discarded bottle should, if possible, be returned to the nearest blood depot or regional centre for investigation.

Dried serum and plasma

Dried serum and plasma are extremely stable products, and are, therefore, especially valuable where long storage or transport under difficult conditions is envisaged. They should be kept in a dark cool place—refrigeration is not necessary.

Reconstitution of Dried Products

To Reconstitute Dried Serum or Plasma

The Medical Research Council bottles used for issue of dried products contain the solids from 400 c.c. of normal human serum or citrated plasma. With each bottle, 400 c.c. of sterile distilled water are supplied, either in a flat medicine bottle or in another Medical Research Council bottle. To reconstitute, unscrew the cap of one of the bottles containing the dried serum or plasma (if possible, flame the top of each bottle) and then pour the distilled water into this bottle and re-cap it immediately. Solution is helped by shaking the bottle and by warming to 37°C, and should then be complete within a few minutes. The presence of a few small undissolved lumps does not matter, as they are removed by the filter. The reconstituted fluid appears turbid. If, in special cases, it is wished to give fluid with a higher protein concentration, less diluent may be added ; thus, the addition of 200 c.c. of distilled water will give a serum or plasma of twice normal concentration, i.e. containing 14 per cent. of protein in the case of serum or 8—9 per cent. in the case of plasma. The concentration of the electrolytes is, of course, also doubled. Concentrated serum or plasma is thought by certain observers to be particularly valuable in burn shock, since the increased protein content appears to favour the reduction of local oedema and burned patients are particularly liable to develop hypoproteinaemia. Other observers consider concentrated products more liable to cause reactions. Sterile normal saline or 5 per cent. glucose solution may also be used as diluent if preferred. *Dried serum or plasma, after reconstitution, should be used without delay. It should not be stored for future use.*

Inspection of Blood or Blood Products before Administration

(i) When removed from the refrigerator for use, every bottle of blood should be carefully inspected. If there is undue haemolysis in the supernatant plasma, or if the colour of the sedimented cells is bluish rather than red, the bottle is unfit for use and should be discarded. *Personnel inexperienced in transfusion work should not be allowed to select bottles for use.*

(ii) Liquid serum or plasma, other than that which has been reconstituted, should not be given if the fluid is cloudy or contains clots or threads or has a deposit.

Intravenous Administration

Unscrew the metal cap of the Medical Research Council bottle, and insert into the latter the rubber bung of the administering unit. Adjust the screw clip to close the lumen of the rubber tubing. Hang up the bottle by means of the metal band and loop, in such a position that the unit hangs vertically above the vein to be used. Disconnect the needle and the short piece of rubber tubing from the rest of the administering unit, by means of the adaptor, and lay them on a clean towel. Remove the cork from the outer end of the long glass tube, and unscrew the screw clip, holding the male adaptor just below the level of the drip feed (Fig. 4). Fluid will now flow through the administering unit, dispelling all the air. When this has been done, the tubing can be clamped by means of artery forceps or by the screw clip.

The skin over the vein chosen for transfusion is thoroughly cleaned with soap and water, and swabbed with a suitable antiseptic. The veins of the forearm are distended by inflating a sphygmomanometer cuff round the upper arm up to 60–80 mm. Hg, or by other constricting device. The needle with the short length of rubber tubing attached is inserted into the vein. As soon as the blood starts to flow from the female adaptor, the pressure is released and the male and female adaptors joined together. The tubing is now unclamped, and the rate of flow adjusted by means of the screw clip. The needle and

rubber tubing should be firmly strapped in position on the arm. Local anaesthesia, though not essential, since a fine needle is used, may facilitate insertion of the needle. To give a second, third or fourth bottle it is necessary only to change the bottle; the same administering unit may be used, but care must be taken to leave it full of fluid before making the change-over; i.e. the first bottle must not be allowed to empty completely. To effect the change-over, compress the tubing above the drip feed, preferably with a clip or artery forceps, remove the bung from the old bottle, put it into the new bottle and release the clip or artery forceps.

Instructions for the use of the Army pattern apparatus are given on pp. 20 and 22.

Practical Points in the Intravenous Administration of Blood or Blood Products

Choice of Vein

(i) A vein in the antecubital fossa is usually the most prominent and, therefore, if the arm is undamaged, may be used with advantage. A cannula should not be used in the antecubital fossa, since the vein may be needed for further transfusions. If the patient is restless, splint the arm with a back splint.

(ii) If a long transfusion is to be given, a vein in the forearm is often more satisfactory than one in the antecubital fossa, since the patient then has greater freedom of movement.

(iii) If the arms have been injured, it may be necessary to use the internal saphenous vein. In this case, it is wise to cut down and insert a cannula. This vein is to be found in a constant position, just anterior to the internal malleolus. It is wise to splint the limb and tie the foot to the bottom of the bed.

To bring up a Vein

Since it is a great advantage to be able to use a needle, rather than to cut down and tie in a cannula, it is important to bring any available vein into prominence. This can be done in the following ways :—

(i) By constricting the limb proximally, to a degree short of obliterating the arterial pulse distally.
(ii) By warming the limb with hot bottles or hot compresses.
(iii) By tapping the skin over the vein with the finger.
(iv) By the opening and closure of the patient's hand on a roller bandage or other suitable object.

Dosage of Blood (or Blood Products)

No rule as to dosage can be given—each case must be treated on its merits. The blood pressure is the best guide, but it may be misleading, as in young people after injury there is often a compensatory rise in pressure which precedes sudden collapse. The object in an obviously shocked patient should be to raise the systolic blood pressure to 100–110 mm. Hg, and to maintain it there (see pp. 14 and 15).

Rate of Flow

The contents of the first two bottles may be given rapidly if the patient is severely injured, i.e. two bottles full may be given in less than 10–30 minutes. As the condition improves, fluid should be given at a slower rate. In a severely shocked patient, the veins may be so collapsed or even constricted that gravity alone is insufficient to maintain a flow. In such a case, pressure may be applied by means of a Higginson's syringe. If desired, a cotton-wool filter may be inserted between the Higginson's syringe and the air-entry tube, but the effectiveness of such a filter is open to question. The needle must be in the lumen of the vein before pressure is applied; and pressure must be released when the bottle is three-quarters empty, to obviate the danger of air embolism.

Temperature

Considerable difference of opinion exists as to whether blood and blood products should be warmed to body temperature before administration. More precise observations are required on this point. Overheating of blood results in haemolysis, and *warming, if deemed necessary, should be carried out only by the sister-in-charge or by a medical officer.* For this purpose, the bottle should be stood for 20–30 minutes in a bowl of water kept at 37°C. Warming has been advised by some observers when large quantities of blood have to be given to—

(*a*) a severely shocked patient very rapidly, as cold blood run in quickly is likely to set up spasm in the vein (in such a case, serum or plasma should be given while the blood is warmed);
(*b*) a severely ill and anaemic patient, especially if cold agglutinins are present in the recipient's serum.

Grouping

In the case of blood, direct matching (see *Medical Research Council War Memorandum No. 9, p. 9*) should be carried out wherever possible before transfusion. Serum and plasma are made from large pools and have an insignificant agglutinin titre. Under these conditions they can be administered irrespective of the group of the patient.

Intramedullary Administration

In certain cases, the intravenous route may be impracticable, owing to the severity of the injuries, or because of venous spasm. This is particularly true in the case of burns. Fluids may then be administered into the marrow cavity. In adults, and in children over 2 years, the sternum is the most convenient site ; in infants the tibia may be used. If necessary, the needle may be inserted through a burned area. Instead of the usual administering needle, the Salah sternal puncture needle, or a shortened administering or taking needle, may be used. If nothing else is available, a sawn off lumbar puncture needle is effective.

Sternum

The patient should, if possible, lie flat in bed, the head being supported with one pillow. The manubrium is chosen for preference, but, if necessary, the first or second part of the sternum may be used. After cleaning the skin, infiltrate it, the subcutaneous tissues and the periosteum, over a point in the midline, with local anaesthetic, using about 2 c.c. Taking the needle in the right hand, insert it vertically with a slight rotary movement through the infiltrated area into the marrow cavity. It should be remembered that in young adults considerable force may be required ; the risk of going through into the mediastinum is slight, since the passage of the needle through the bone into the marrow cavity is usually readily appreciated even by an onlooker. There is a sudden " give," and often an actual " scrunch " is heard, as the cavity is reached. If a Salah needle is used, as soon as the cavity is entered the stilette is withdrawn, a syringe attached, and in order to determine that the marrow cavity has been entered, a small amount of marrow tissue is withdrawn by suction. In some individuals it may be necessary to apply repeated suction with the syringe before marrow is obtained. The sensation of entering the cavity is so characteristic that failure to withdraw marrow should not prevent the continuation of the transfusion. By means of the syringe, the cavity of the needle should be filled with saline or citrate solution, and a connection with the rest of the administering unit, prepared as for an ordinary intravenous transfusion, may then be made. If the rate of flow is too slow, pressure may be exerted by means of a Higginson's syringe or other pressure device. As much as 14 litres of fluid have been given by this route over a period of days to one patient. If the flow stops, it may be restarted by shifting the position of the needle without withdrawing it, or by disconnecting the administering unit and first aspirating a little marrow or else inserting some sterile citrate solution by means of a syringe.

Tibia

Splint the leg with a straight splint applied to the outer aspect of the leg, and keep in position by ties from the foot to mid-tibia and from the lower to the upper thigh. The site of puncture is the antero-medial surface of the tibia at the level of the tibial tubercle, which can be easily felt even in the youngest infant. The skin is cleaned with soap and water, and an antiseptic, and a local anaesthetic injected into the skin, subcutaneous tissues and periosteum. The puncture needle is then inserted at right angles to the plane of the antero-medial surface of the tibia, as nearly as possible half-way between the anterior and medial borders of the bone. The needle should be inserted distally, i.e. away from the epiphyseal line, but a needle absolutely vertical in all planes should miss the epiphyseal line. The soft bone of an infant is punctured easily, and gives the feeling of stale cheese ; no marked " give " is noted when the marrow cavity is entered. Entry is usually attained about one-eighth to three-sixteenths of an inch below the periosteum, and can be proved by the aspiration of marrow. The procedure is then the same as for sternal puncture. The transfusion tends to be slow at first, and to increase in rate spontaneously after 5 to 10 minutes. The transfusion, therefore, in infants usually has to be slowed from time to time, rather than quickened as in the adult.

APPENDIX D

Reconditioning of Apparatus for Repeated Use

Cleansing of Apparatus after Use

All apparatus, except the bottle, must be rinsed out immediately after use, preferably with a weak sodium carbonate solution, and cleaned thoroughly as soon as possible. The bottle, containing a few c.c. of the transfusion fluid, should be stored for 24 hours in a cool place, preferably a refrigerator, in case a sample is required for laboratory investigation.

Bottles

Wash with a hard brush in water containing a detergent. Soapy water may be used, but an abrasive should not be employed. An alternative method is to boil the bottles for half an hour in a weak solution of washing soda (2 oz. to the gallon), and then rinse them in 5 per cent. hydrochloric acid. Whichever method of cleaning is employed, the bottles must subsequently be rinsed in tap water and, if possible, in distilled water. They are then allowed to drain and dry, neck downwards.

Bottle Caps

The rubber wads must be removed from the aluminium caps, and both must be well washed in soapy water and dried separately. When the caps are first received from the manufacturer, the wads should be boiled in order to clean them thoroughly. This is not necessary on subsequent occasions.

Glass Tubing and Glass Drippers, etc.

Soak in chromic acid (10 per cent. potassium dichromate in concentrated sulphuric acid) for 4–7 days, then wash thoroughly with running water, followed by distilled water, and dry in an oven at 120° C.

Rubber Bungs

Wash in hot soapy water, rinse in tap water and dry on a close wire-netting tray on top of a warm oven.

Rubber Tubing

Wash through with water under pressure. A stiff wire carrying a swab or narrow elongated brush (for example, a 0·22 rifle barrel cleaner) should be drawn throughout the length of rubber tubing (since washing under a tap is insufficient to remove adherent pieces of clot) ; the tubing is then again washed through with water and dried in air.

Gas-mantle Filter

It is usually more economical of time and labour to discard the gas-mantle filter, but in case of necessity it may be cleaned with hydrogen peroxide or by boiling, and used again.

Wire-gauze Filter

Soak in water overnight, brush with a stiff brush and wash under pressure ; dry on top of a hot oven. Hydrogen peroxide may also be used to clean this filter.

Needles

These must be washed through with tap water under pressure, the bore cleaned thoroughly with a stiletté, and the butt with cotton wool on the end of a swab stick. The needles are then sharpened, and again washed through with water under pressure. After sharpening on an Arkansas stone or by other means, they may be soaked in trichlorethylene and then dried with spirit and ether.

N.B.—All glassware should be rinsed with distilled water if possible ; this, however, may prove impracticable under emergency conditions.

Sterilisation

If an autoclave is available

All bottles, taking and administering outfits, should be autoclaved. To sterilise the bottles, the metal cap and rubber diaphragm may be fitted loosely on the neck during autoclaving, covered with a well-fitting linen cap and screwed tight during removal of the bottle from the autoclave when hot. If preferred, the bottles may be autoclaved with the caps screwed tight. The metal cap and the bottle neck should subsequently be covered with a cellulose or paper cap, the air pressure in the bottle having previously been brought into equilibrium with that outside by admission of sterile air through a cotton wool filter. Bottles which do not contain anticoagulant should have at least 5 c.c. of normal saline added prior to sterilisation. The administering and taking units, are wrapped in "Cellophane" and packed into tins of suitable size. The lids of the tins should rest lightly on the tins during autoclaving, and be closed down tight on removal from autoclave. In the autoclaves supplied to the Emergency Transfusion Service, a pressure of 20 lb. should be maintained for 20 minutes, care being taken to remove all air. Drums and tins containing administering or taking units must be dried off in an oven at 120° C. after autoclaving. It is important to remember that rubber tubing should not be allowed to kink ; free access of boiling water or steam to all parts of the lumen is essential for proper sterilisation.

If an autoclave is not available

Bottles, glass tubing, rubber tubing and rubber bungs can be sterilised by boiling for 20 minutes, preferably in freshly prepared pyrogen-free citrate solution. The needles can be sterilised in liquefied phenol (acidum carbolicum liquefactum) or pure lysol (rinsing in sterile saline before use) or in hot oil. The wire-gauze filter may be boiled in saline or citrate solution.

APPENDIX E

Concentrated Red Cell Suspension

Although in the initial treatment of wound " shock " the transfusion of whole blood, or serum or plasma in their liquid or reconstituted dried forms, is the best means of restoring blood volume, concentrated red cell suspension may be of value in combating any subsequent anaemia. Such suspension is prepared by taking two Medical Research Council bottles of whole citrated blood of the same group, in which maximum sedimentation of the red cells has occurred (usually 5–6 days after date of collection). The supernatant plasma in each is syphoned off, and the red cell deposit in one bottle added to that in the other, the mixture being topped up to the 540 c.c. mark with a small volume of saline, preferably hypertonic (1·1 per cent.). Sterile precautions are maintained throughout, and it is advisable that the suspension be used only within a few hours of its preparation.

The anticipated rise in haemoglobin resulting from the transfusion of one Medical Research Council bottle of whole blood (with the usual proportion of anticoagulant solution) is approximately 8 per cent. (Haldane scale) in an adult, in the absence of simultaneous blood loss or blood dilution. With concentrated red cell suspension under similar conditions, a rise of about 15 per cent. per bottle may be obtained. The reaction incidence is probably less than with whole blood, serum or plasma.

(67627) Wt. 2443/930 11/44 Hw. G.344 S.O. Code No. 45-9-1-44*